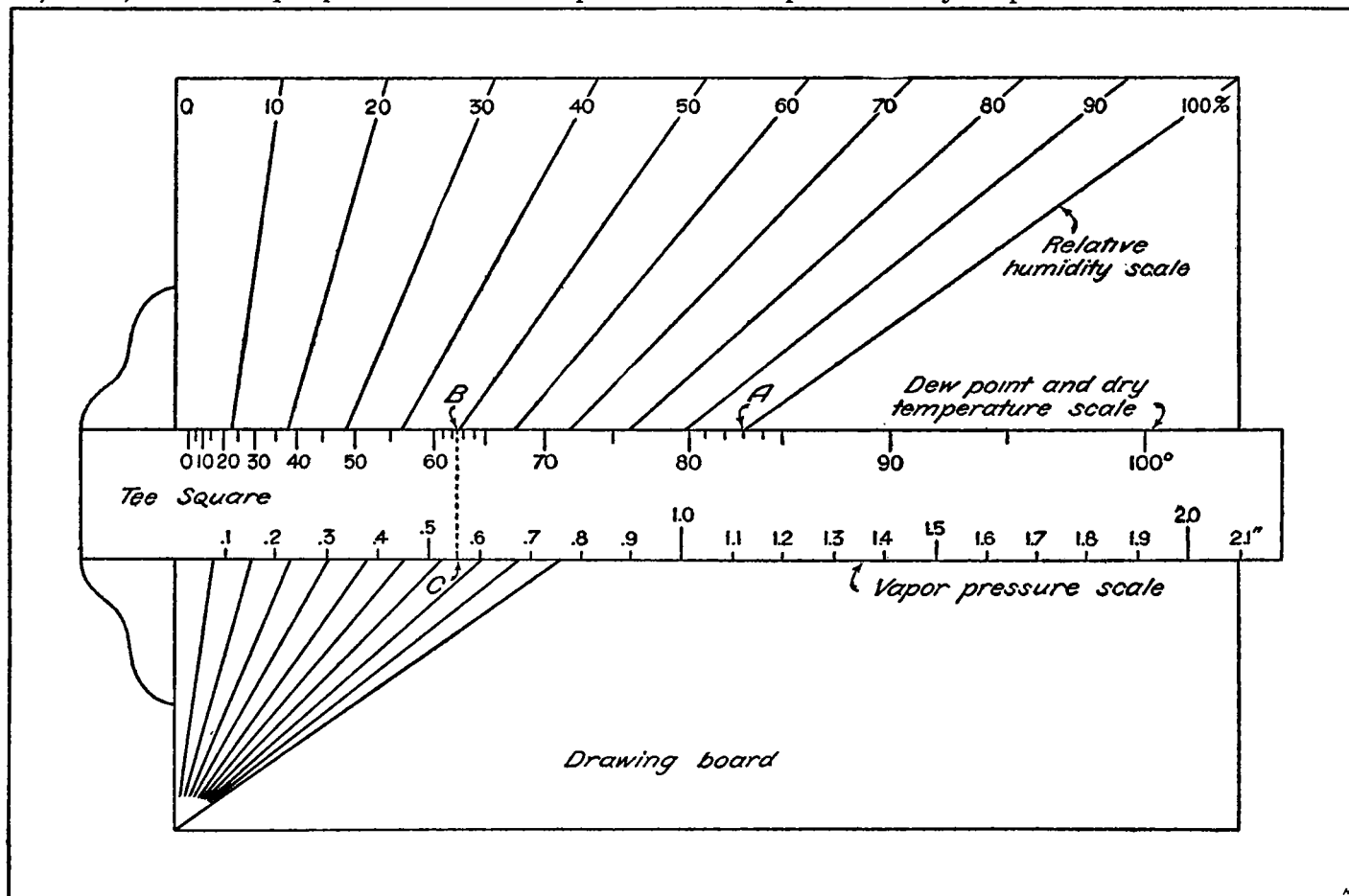


tion vapor pressure for a temperature of 82.8°, each humidity line cuts the blade vapor pressure and temperature scales at proportional points. In this case, 50 percent relative humidity cuts the dew point scale at 62.6°, at B, and the vapor pressure at this dew point is

The device possibly may be useful at some airways stations in rapidly computing relative humidity from dry temperature and dew point, as given in hourly observations; and at fire weather stations, for calculating values of dew point from dry temperature and relative humidity,



0.567 inch, at C. If the dry temperature again is 82.8°, and the dew point 23°, without changing the setting, it is apparent that the relative humidity is 10 percent. In other words, as set in this example, the device shows every related hygrometric factor (except wet bulb temperature or wet bulb depression) for a dry temperature of 82.8°.

on form 1009-E. All necessary data for construction of the scales appears in the dew point and equivalent vapor pressure columns of W. B. Pub. No. 235, Psychrometric Tables by C. F. Marvin.

## THE PRINCIPLES UNDERLYING THE CHOICE OF VISIBILITY MARKS<sup>1</sup>

By W. E. KNOWLES MIDDLETON

[Meteorological Service of Canada, Toronto, Ontario, December 1934]

The estimation of the distance of visibility, or "visual range", by eye is probably one of the least satisfactory of all meteorological observations. Quite apart from the excellence or otherwise of the observer's eyesight, it must be recognized that this element depends to a large extent upon the nature of the marks at which he can look.

What are the criteria of a satisfactory method of determining the visual range? Surely they cannot be very different from those which apply to any other observation; we shall suggest two:

(1) Observations made at different stations shall be intercomparable.

(2) Observations made by night shall be comparable with those made by day.

It will be the purpose of this note to suggest procedures by means of which these conditions may at least be approximated.

It has been shown (6) (7) (8) that the visual range of a black object against the horizon sky is given by the formula

$$S_v = \frac{1}{\sigma} \ln 50 = \frac{3.912}{\sigma} \quad (1)$$

where  $\sigma$  is the extinction coefficient<sup>2</sup> of the atmosphere in the horizontal. This formula is independent of azimuth, and holds if the sky is cloudless or completely clouded.

<sup>1</sup> The extinction coefficient is defined by the equation

$$dE = -\sigma E dx,$$

where  $E$  is the flux-density in a parallel beam of light traveling in the direction of  $x$ . It is a convenient measure of the obscurity of the atmosphere at a given time and place.

<sup>2</sup> Published by permission of the Director of the Meteorological Service of Canada.

A gray object of albedo (diffuse reflection coefficient)  $R$ , seen against the horizon sky has the visual range

$$S = \frac{1}{\sigma} \ln \left[ 50 \left( 1 - \frac{R}{2} \right) \right] \quad (2)$$

provided that the sky is uniformly clouded (3). This differs very little from (1) if  $R$  is less than 0.2. Against a terrestrial background of albedo  $R_1$ , the visual range will be (3)

$$S_1 = \frac{(1/\sigma) \ln [25(R - R_1)]}{(1/\sigma) \ln [25(R_1 - R)]} \quad \begin{matrix} (R > R_1) \\ (R_1 > R) \end{matrix} \quad (3)$$

We have no space here to give the derivation of these formulae for which the original papers must be consulted. The important fact to be noted is that for all but the black object it is necessary to stipulate a uniformly clouded sky, and also to know the albedo of the object or objects concerned. If the sun is shining, the visual range of the gray objects shows a large dependence on azimuth; a dependence, moreover, which has resisted all attempts at simple formulation. When there are broken clouds, the visual range will of course vary from one place to another, owing to the differing illumination in different places.

The same coefficient  $\sigma$  enters into the expression for the visual range of lights at night (3). This distance is given by  $S_n$  where

$$\frac{I_0}{S_n^2} e^{-\sigma S_n} = E, \quad (4)$$

in which  $I_0$  is the candle-power of the light and  $E$  is the threshold flux-density, or the least flux density at the eye which will render a point source visible (9). Equation 4 is best solved graphically.

The present techniques of estimating the visual range entirely ignore the implications of these equations. All sorts of objects, some against the sky, some against terrestrial backgrounds, are used during the daytime; and at night there is a similar lack of care in the choice of lights, with only a warning against observing a beacon (11) or a "powerful lighthouse" (10). The result is that neither of the above criteria is satisfied.

If we restrict our choice of daytime objects to black objects against the sky, it follows from (1) that each value of  $S_s$  corresponds to a unique value of  $\sigma$ . It is therefore possible to construct a table showing corresponding values of  $\sigma$  and  $S_s$ , as in table 1.

TABLE 1

Extinction coefficient $\sigma$	Visual range $S_s$ of black object	Extinction coefficient $\sigma$	Visual range $S_s$ of black object
$km^{-1}$	$km$	$km^{-1}$	$km$
78.0	0.050	1.68	2.33
36.2	.108	.780	5.00
16.8	.232	.362	10.8
7.80	.500	.168	23.5
3.62	1.08	.078	50.0

The reasons for the choice of values in table 1 need not concern us here—they form a geometric progression in  $\sigma$ , and happen to lie near the values in the international code for visibility. The important point is that *when we make an accurate estimate of the visual range of a black object against the sky we are in effect measuring  $\sigma$ , which is a property of the atmosphere.* Even if the object is not

quite black, the difference is not great, as is shown by table 2, as long as it appears against the sky.

TABLE 2.—Visual range of black and dark gray objects for  $\sigma = 1.0 km^{-1}$ 

Albedo of object, $R$	Visual range, $S$
	$km$
0.00 (black)	3.91
.01	3.90
.04 (woods)	3.88
.07	3.86
.10	3.85
.15	3.82
.20	3.80

On the other hand, the visual range of a wood ( $R=0.04$ ) against a plowed field ( $R=0.24$ ) is only 1.61 km under similar conditions of obscurity. In order to fulfill our first criterion, therefore, it will be well to confine our daytime observations to black objects against the sky, wherever they can be obtained. The values given above suggest that it is better to interpolate between good objects than to accept unsatisfactory ones.

The second condition can be satisfied only if a certain visual range observed by day refers to the same value of  $\sigma$  as the same visual range observed at night. It will be seen from equation 4 that it is theoretically possible to choose a light-source for each distance in such a way that this is so. Table 3 shows the results of doing this, using the distances and values of  $\sigma$  in table 1.

It is obvious that at no station will there be such an array of lights, and it is difficult to see what can be done to make night observations comparable with daytime ones, unless a transmission meter (1)(2)(4)(9) is used. Probably the best that can be done is to adopt some convenient intensity as a standard for the lower visual ranges, in order to serve the aviator as well as possible.

The writer (9) suggested a 100-candle power lamp as a standard for the lower visual ranges, since it is of the order of magnitude of airport boundary lights. Using a transmission meter, the resulting values of  $\sigma$  could easily be converted into visual ranges for such a lamp; curves suited to this purpose have been published by Foitzik (3)(5). The aviator could then accept the measurements with the confidence that he could see a boundary light at the distance given by the "visibility" in the weather report.

The objection may be raised that tables 1 and 3 are not strictly comparable because of the variation of  $\sigma$  with the wavelength, the color temperature of incandescent lamps being lower than that of daylight. This is a legitimate criticism at the greater visual ranges; but at the shorter distances the variation of  $\sigma$  becomes much less.<sup>3</sup> Also, since  $\sigma$  for the lamp is always less than for daylight, table 3 is on the safe side as regards the candle power of the necessary lights.

TABLE 3.—Visual range of lights at night

Extinction coefficient $\sigma$	Visual range $S_n$	Intensity of source $I_0$	Remarks
$km^{-1}$	$km$	$candels$	
78.0	0.050	0.04	These values of $I_0$ are calculated on basis of $E$ , the threshold of vision, having the value $E=3.5 \times 10^{-7}$ meter-candles or 0.35 lumens $km^{-2}$ .
36.2	.108	.2	
16.8	.232	1.0	
7.80	.500	4.4	
3.62	1.08	20	
1.68	2.35	95	
.780	5.00	437	
.362	10.8	2,040	
.168	23.5	9,500	
.078	50.0	43,700	

<sup>3</sup> Evidence for this is to be presented by the writer in a paper to be published in the near future.

We may formulate the general conclusions (1) that for observations in the daytime it is advisable to confine our choice of marks to black, or nearly black, objects against the horizon sky, rejecting marks which appear against terrestrial backgrounds; and (2) that the general adoption of some sort of transmission meter is desirable in order to make night measurements independent of local conditions.

It is felt that some standardization of technique on the lines here suggested would greatly improve the quality of observations of the visual range. It is a common opinion that observations of this element are of no use in synoptic meteorology. May it not be possible that this has been true in the past only because such data are not inter-comparable?

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## CLIMATIC TREND IN THE PACIFIC NORTHWEST

H. G. CARTER, Meteorologist

[Weather Bureau, Boise, Idaho, January 1935]

Numerous studies have been made of weather conditions in various sections of the country in an effort to determine whether climate has undergone any progressive change in one definite direction within the memory of the present generation.<sup>1</sup> With the view of contributing to the data already collected for this purpose, the writer made a study of the weather in the Pacific Northwest.

The Weather Bureau records at Portland, Oreg., and Seattle, Wash., were considered as representative of the coast climate of the Pacific Northwest, and the records at Boise, Idaho; Spokane, Wash.; and Walla Walla, Wash., as representative of the climate of the interior stations.

## PRECIPITATION

Table 1 gives the annual precipitation at each of the five stations from the beginning of the records down to and including 1933, and figure 1 shows graphically the same data. A glance at the chart emphasizes the variations in precipitation from year to year. Wet and dry years follow each other irregularly by no set rule. A study of the chart reveals the difficulty of finding cycles of wet or dry years. At Portland the unusually wet year of 1882 stands in sharp contrast to the dry year of 1929. The annual amounts, when represented in inches, show greater variations at the coast stations, as amounts for the year are larger than at the interior stations. It is interesting to note the frequent similarity in the trend of the graphs representing the amounts at the different stations.

TABLE 1.—Annual precipitation

Year	Portland	Seattle	Boise	Spokane	Walla Walla
1868			6.69		
1869			15.73		
1870			15.93		
1871			25.80		
1872	46.90		17.33		
1873	50.52		17.74		13.13
1874	46.17		14.97		11.84
1875	60.10		13.83		15.91
1876	54.94		11.12		17.32

TABLE 1.—Annual precipitation—Continued

Year	Portland	Seattle	Boise	Spokane	Walla Walla
1877	58.30		13.80		20.56
1878	47.70	42.60	9.02		13.64
1879	62.22	56.44	15.17		20.48
1880	51.87	42.92	10.66		17.71
1881	57.05	46.81	13.56	24.68	22.27
1882	67.24	36.71	14.43	25.99	20.87
1883	51.45	30.32	15.17	14.37	12.56
1884	38.31	30.35	21.05	20.56	20.61
1885	39.59	38.25	12.56	19.01	15.31
1886	38.76	31.13	12.23	15.86	16.20
1887	54.17	35.63	11.34	20.10	20.44
1888	38.76	34.77	11.06	17.69	13.59
1889	31.76	25.92	10.95	14.27	14.53
1890	40.38	26.94	12.53	16.57	11.80
1891	47.41	34.74	13.31	16.69	16.11
1892	32.58	32.49	11.75	16.78	16.94
1893	39.08	45.16	13.92	22.00	23.07
1894	39.32	41.08	14.12	17.84	20.49
1895	30.76	29.69	7.90	13.46	14.89
1896	44.13	42.83	22.95	20.32	19.41
1897	43.01	41.53	16.98	23.84	21.67
1898	35.90	29.28	8.85	13.08	16.34
1899	42.21	37.13	14.84	20.08	22.99
1900	38.22	36.48	12.77	18.72	18.89
1901	41.05	30.18	9.59	15.99	14.52
1902	50.15	45.78	12.15	19.23	18.88
1903	35.62	34.55	9.55	16.55	15.70
1904	46.37	37.73	14.08	13.97	18.13
1905	34.10	34.35	9.77	16.68	17.12
1906	43.29	36.67	14.19	17.60	19.13
1907	42.89	29.10	15.92	17.69	15.77
1908	34.37	28.25	12.33	12.02	11.66
1909	43.75	31.72	15.06	16.21	18.73
1910	38.65	34.20	12.07	15.44	16.82
1911	33.28	21.69	15.35	11.86	13.38
1912	43.47	35.14	18.10	18.21	20.36
1913	36.30	24.59	16.04	16.74	17.38
1914	36.67	31.43	8.60	13.56	13.60
1915	41.30	33.83	13.31	16.35	17.08
1916	45.77	34.61	14.64	15.75	21.32
1917	40.50	28.90	14.48	11.88	15.90
1918	31.50	29.21	12.73	9.92	12.25
1919	45.70	31.54	11.46	13.85	16.64
1920	41.17	32.21	13.57	12.18	18.43
1921	43.21	39.81	12.07	12.62	16.41
1922	38.76	25.27	12.00	11.51	11.15
1923	32.81	27.18	12.47	16.02	17.19
1924	31.22	30.73	8.66	12.25	13.06
1925	31.36	25.78	13.79	12.35	11.71
1926	41.17	26.12	11.65	14.52	17.90
1927	45.78	32.98	15.41	23.28	18.51
1928	34.69	25.60	9.53	10.56	12.44
1929	26.11	20.03	8.83	7.54	11.19
1930	27.16	21.78	14.46	11.84	13.22
1931	42.68	36.06	9.41	13.61	16.87
1932	39.98	34.28	13.09	15.85	14.76
1933	52.85	44.91	7.95	14.91	16.22
Average	42.25	33.66	13.22	16.05	16.61

<sup>1</sup> Kincer, J. B.: Is Our Climate Changing? A Study of Long-Time Temperature Trends. MONTHLY WEATHER REVIEW, vol. 61, September 1933, pp. 251-269.